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Transportation Cask Receipt Return Facility	140-00C-CC00-00200-000-00B

5. Title

Transportation Cask Receipt and Return Facility Worker Dose Assessment

6. Group

Environmental and Nuclear Engineering/Radiological Engineering

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An LP-2.14Q-BSC review was completed on February 16, 2005

Attachments	Total Number of Pages
Attachment I Listing of Electronic File in CD Containing Worker Dose Calculations	1

RECORD OF REVISIONS

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00B	Revised extensively due to added calculation of worker exposure to radiation while performing inspection and survey of casks at the site gate. Used universal transport cask dose rate characteristics for worker dose calculation. Updated References	29	I-1	V. Arakali SIGNATURE ON FILE 2/24/2005	Y. Yuan SIGNATURE ON FILE 2/24/2005	D. J. Tunney SIGNATURE ON FILE 2/24/2005	A.G. Ogurek SIGNATURE ON FILE	2/24/05

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TABLES

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ACRONYMS

ALARA	as low as is reasonably achievable
BSC	Bechtel SAIC Company, LLC
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
CHF	Canister Handling Facility
CO	cask operator
DDE	deep dose equivalent
DOE	U.S. Department of Energy
DTF	Dry Transfer Facility
GO	gantry/crane operator
HLW	high-level radioactive waste
HP	health physicist
NRC	U.S. Nuclear Regulatory Commission
PCSA	preclosure safety analysis
PWR	pressurized water reactor
SNF	spent nuclear fuel
SP	security personnel
SRTC	site rail transport car
TCRRF	Transportation Cask Receipt and Return Facility
TEDE	total effective dose equivalent
TP	transportation personnel

UNITS OF MEASURE

Bq	Becquerel
Ci	Curie
Dpm	disintegration per minute
ft	feet
hr	hour
m	meter
min	minutes
mrem	millirem
Sv	Sievert
s	second

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1. PURPOSE

The purpose of this design calculation is to estimate radiation doses received by personnel working in the Transportation Cask Receipt and Return Facility (TCRRF) of the repository including the personnel at the security gate and cask staging areas. This calculation is required to support the preclosure safety analysis (PCSA) to ensure that the predicted doses are within the regulatory limits prescribed by the U.S. Nuclear Regulatory Commission (NRC).

The Cask Receipt and Return Facility receives NRC licensed transportation casks loaded with spent nuclear fuel (SNF) and high-level radioactive waste (HLW). The TCRRF operation starts with the receipt, inspection, and survey of the casks at the security gate and the staging areas, and proceeds to the process facilities. The transportation casks arrive at the site via rail cars or trucks under the guidance of the national transportation system.

This calculation was developed by the Environmental and Nuclear Engineering organization and is intended solely for the use of Design and Engineering in work regarding facility design. Environmental and Nuclear Engineering personnel should be consulted before using this calculation for purposes other than those stated herein or for use by individuals other than authorized personnel in the Environmental and Nuclear Engineering organization.

2. QUALITY ASSURANCE

This document was prepared in accordance with AP-3.12Q, *Design Calculations and Analyses*. Since the results of this calculation are used to support Preclosure Safety Analysis relative to radiological safety of the TCRRF workers, this document is subject to the requirements of *Quality Assurance Requirements and Description* (DOE 2004 [DIRS 171539], Section 2.2.2).

3. METHOD

The dose assessment involves calculations of annual individual and collective doses to TCRRF workers. These occupational doses are defined as the total effective dose equivalent (TEDE) received by workers involved in TCRRF operations. The TEDE consists of the deep dose equivalent (DDE) from direct exposure (contained sources and airborne radionuclides), summed with the committed effective dose equivalent (CEDE) from inhalation of airborne radionuclides. The calculated doses are based on expected worker occupancy factors and exposure times, area radiation dose rates, distances to radiation sources, and the number of personnel involved in each operation.

The TCRRF provides space, layout, and structures that support waste handling operations. The waste handling operations at TCRRF receive transportation casks at the site entrance. The cask is unloaded from the transportation carrier and integrated with the onsite cask-handling system within the TCRRF protective structure to support the throughput rates established for waste emplacement. The TCRRF also requires interface with other repository systems that perform or support waste handling systems. Work groups comprising the TCRRF personnel are transportation personnel (TP), cask operator (CO), health physicist (HP), gantry/crane operator (GO), and security personnel (SP). TP duties include the movement of a full or empty cask/carrier into and out of the transfer bay. CO and GO function together and their duties involve removal of personnel barriers/impact limiters, cask transfers from carrier to site rail transport car (SRTC), and inspection. HP monitors radiation and contamination levels during cask receipt and transfer. SP provides security functions at the receiving station. A detail of process steps given in Table 1 is based on Cogema BFD Level 2 [DIRS 168964].

The dose assessments are performed by job function or worker groups using the time-distance inputs and dose rates estimated at various worker locations (see Table 1).

Table 1. Transportation Cask Receipt and Return Facility Process Steps

TCRRF Process Step			Expected Duration[a] (min)	Worker Distance (m)[a]/ Dose Rate[b] (mrem/hr)				
CASK Staging Activities								
0.0	**Receive, inspect, and drive cask to transfer bay**		**65**	**TP**	**CO**	**HP**	**GO**	**SP**
	0.1	Verify transportation document	5	2/5.36				
	0.2	Inspect vehicle/cask for any damage	10		1/8.90			
	0.3	Security vigilance	10					1/8.90
	0.4	Radiological survey	10			1/8.90		
	0.5	Drive to transfer bay	15	2/5.36				
	0.6	Rad tech escort	15			2/5.36		
CASK from CARRIER to Transfer Bay and BUFFER								
1.0	**Receive carrier/cask in transfer bay**		**15**	**TP**	**CO**	**HP**	**GO**	**SP**
	1.1	Open exterior door	0					
	1.2	Move carrier/cask into transfer bay with prime mover	15	5/1.72	10/.54	10/.54	10/.54	
	1.3	Disconnect and move prime mover outside	0					
	1.4	Close exterior door	0					
2.0	**Remove personnel barrier and impact limiters, perform inspection/survey**		**155**	**TP**	**CO**	**HP**	**GO**	**SP**
	2.1	Prepare crane for personnel barrier removal	15		10/.54	10/.54	5/1.72	
	2.2	Remove and stage personnel barrier	30		1/8.90	10/.54	5/1.72	
	2.3	Prepare crane for impact limiters removal	15		10/.54	10/.54	5/1.72	
	2.4	Remove and stage impact limiters	40		1/8.90	10/.54	5/1.72	
	2.5	Inspect cask for damage (visual)	15		1/8.90	10/.54	10/.54	
	2.6	Perform contamination and radiation survey on accessible areas	10		10/.54	1/8.90	10/.54	
	2.7	Replace and secure impact limiters	30		1/8.90	10/.54	5/1.72	
	2.8	Prepare empty SRTC and position nearby	0					

Table 1. Transportation Cask Receipt and Return Facility Process Steps (Continued)

TCRRF Process Step			Expected Duration[a] (min)	Worker Distance (m)[a]/ Dose Rate[b] (mrem/hr)				
3.0	**Transfer cask from carrier to SRTC**		**95**	**TP**	**CO**	**HP**	**GO**	**SP**
	3.1	Prepare crane, load cask lifting yoke on crane hook.	0					
	3.2	Adjust universal lifting yoke to suit specific cask	5		1/8.90	10/.54	5/1.72	
	3.3	Mount lifting lugs on skid or trunnions on cask	15		1/8.90	10/.54	5/1.72	
	3.4	Engage lifting yoke with skid lifting lugs or cask trunnions	5		10/.54	10/.54	5/1.72	
	3.5	Remove cask skid tie-downs	15		1/8.90	10/.54	5/1.72	
	3.6	Transfer cask/skid from carrier to SRTC	15		10/.54	10/.54	5/1.72	
	3.7	Secure cask/skid to SRTC	15		1/8.90	10/.54	5/1.72	
	3.8	Disengage cask lifting yoke	5		1/8.90	10/.54	5/1.72	
	3.9	Withdraw cask crane to staging area	0					
	3.10	Retrieve personnel barrier and re-install on cask/skid	20		1/8.90	10/.54	10/.54	
4.0	**Transfer SRTC/cask from transfer bay to buffer[c]**		**85**	**TP**	**CO**	**HP**	**GO**	**SP**
	4.1	Open transfer bay door(s)	0					
	4.2	Retrieve carrier prime mover and SRTC tractor	0					
	4.3	Connect prime mover and undock carrier and move out of transfer bay	15	5/1.72				
	4.4	Close transfer bay external door	0					
	4.5	Return empty carrier to rail or truck queuing yard/parking	15					
	4.6	Retrieve SRTC tractor and connect to SRTC	15	5/1.72				
	4.7	Move SRTC/cask to SRTC positioner	10	5/1.72				
	4.8	Close transfer bay external door	0					
	4.9	Move SRTC positioner/cask to align with desired staging location	10	5/1.72				
	4.10	Retrieve SRTC tractor and move SRTC/cask into desired staging location	10	5/1.72				
	4.11	Disconnect tractor from SRTC/cask	0					
	4.12	Rad tech oversee operation	10			15/.34		
CASK from BUFFER to DTF/CHF								
5.0	**Transfer cask from buffer to DTF or CHF[c]**		**315**	**TP**	**CO**	**HP**	**GO**	**SP**
	5.1	Retrieve SRTC tractor and connect to SRTC/cask	15	5/1.72				
	5.2	Move SRTC/cask from staging location onto SRTC positioner	10	5/1.72				

Table 1. Transportation Cask Receipt and Return Facility Process Steps (Continued)

TCRRF Process Step			Expected Duration[a] (min)	Worker Distance (m)[a]/ Dose Rate[b] (mrem/hr)				
	5.3	Disconnect tractor from SRTC/cask	10	5/1.72				
	5.4	Move SRTC positioner/cask from buffer to DTF or CHF	250	5/1.72				
	5.5	Retrieve SRTC tractor and connect to SRTC	10	5/1.72				
	5.6	Move SRTC/cask to the entrance of DTF/CHF	10	5/1.72				
	5.7	Rad tech oversee operation	10			15/.34		
	5.8	Tractor can be left connected to SRTC/cask	0					

NOTES: [a] Expected exposure time are based on anticipated values when compared to similar activities as reported in General Atomics 1993 [DIRS 104776], Table 7.5-3.

[b] Dose rates are from Table 3, Column C

[c] These steps are followed in reverse order to return empty cask to transfer bay. Return of empty cask is mainly performed in non-radiation area except in buffer area. Dose received in buffer area is assumed to be the same as if the cask is loaded for a conservative estimate.

CHF: Canister Handling Facility

4. DESIGN INPUTS

This dose assessment calculates annual individual and collective doses received through process steps performed by the TCRRF workers. Design inputs include the list of process steps, exposure times, and source term dose rates as a function of distance to the worker. (Table 1)

4.1 PROCESS STEPS TIME-DISTANCE INPUTS

The five different work groups in the TCRRF perform duties that will require different exposure time at different distances from the transportation cask. Table 1 displays the process steps, and expected exposure times and distances of the TP, CO, HP, and GO worker types in the TCRRF and SP at the transporter receiving gate. Process steps are preliminary at this time, but it is intended that Table 1 is as detailed as possible about process steps in the TCRRF. Expected exposure distance and time for task completion in the TCRRF are based on anticipated values when compared to similar activities as reported in General Atomics 1993 [DIRS 104776], Table 7.5-3.

4.2 EXTERNAL DOSE FROM TRANSPORTATION CASK

4.2.1 Dose Rates as a Function of Distance for Universal Transport Cask

Per Assumption 4.3.1, the dose rates received by TCRRF workers at various distances from a transportation cask are derived from the 2 m dose rates of the universal transport cask (NAC International 2002) and the radial dose distance factors are derived based on the methodology developed in BSC 2004 [DIRS 171772], Attachment I. Per Table 1, workers are modeled to be at 1, 2, 5, 10, and 15 m from the exterior surfaces of a loaded transportation cask. Dose rates at these distances are estimated and described in Assumption 4.3.1. The average dose rates at the five distances are 8.9, 5.36, 1.72, 0.54, and 0.34 mrem/hr, respectively. These dose rates are used in worker dose assessment of the TCRRF.

Tables 2 and 3 summarize the TCRRF worker dose rates versus distance described in Assumption 4.3.1.

Table 2. 2 m Dose Rates (mrem/hr) of Universal Transport Cask

	Dose Rate [A]	Scaled Dose Rate [B]
Radial [C]	9.6	10.00 (bounding)
Top Axial [D]	0.1	0.10
Bottom Axial [E]	1.3	1.35
Weighted Average [F]	5.15	5.36

Source: Column [A]: From NAC International 2002 [DIRS 164612], Table 5.1-1
Column [B] = Column [A] x 10.0 / 9.6. Scaled dose rate is discussed in Assumption 4.3.1
Row [F] = 0.5 x Row [C] + 0.25 x Row [D] + 0.25 x Row [E] (BSC 2004 [DIRS 171772], Attachment I)

Table 3. Estimated Dose Rates for A Typical Rail Cask

Distance [A]	Dose Distance Factor [B]	Dose Rate (mrem/hr) [C]
1 m	1.66	8.90
2 m	1.00	5.36
5 m	0.32	1.72
10 m	.0998	0.53
15 m	.0633	0.34
20 m	.0669	0.144

Source: Column [A] from Col 1 of BSC 2004 [DIRS 171772], Table I-5.
Column [B] from Col 7 of BSC 2004 [DIRS 171772], Table I-5.
Column [B] row 6 interpolated distance factor between 10 and 20m
Column [C]: 5.36* Col [B]

4.2.2 External Dose from Contained Source

The annual external dose from the contained source per individual worker is calculated as:

$$ED_g = \Sigma_i \, [DR_{i,g} \times T_i\,] \times (TC/WS) \qquad \text{(Eq. 1)}$$

where:

$DR_{I,g}$ = External dose rate at location i per individual worker per worker group g (mrem/hr).

Ti = Duration of the exposure at location i, per cask operation (hr/cask).

TC = Number of processed transportation casks per year (casks/yr).

WS = Number of work shifts. (Assumption 4.3.2)

4.2.3 Inhalation Dose from Airborne Source

The volumetric flow rate of recycled air in the TCRRF is used as an input to determine the airborne radionuclide concentration. It is calculated as:

$$V = L \times W \times H \times A \times F \times U \qquad \text{(Eq. 2)}$$

where:

V = Volumetric flow rate of air (m^3/s).
L = Length of TCRRF floor plan (m) (see Assumption 4.3.13).
W = Width of TCRRF floor plan (m) (see Assumption 4.3.13).
H = Truncated height of TCRRF (m) (see Assumption 4.3.13).
A = Air change rate (hr^{-1}) (see Assumption 4.3.9).
F = Fraction of outside makeup air (see Assumption 4.3.9).
U = Unit conversion factor from hr to s.

Airborne radionuclide concentration is calculated as:

$$C_i = SC \times SA \times RR \times U/V \qquad \text{(Eq. 3)}$$

where:

C_i = Airborne concentration of respirable radionuclide *i* (Ci/m^3).

SC = Maximum allowable radionuclide surface contamination (Ci/m^2) (see Assumption 4.3.10, note: dpm/cm^2 is converted to Ci/m^2 using 4.5×10^{-9}).

SA = Surface area of 6 casks (m^2) (see Assumption 4.3.12).

RR = Resuspension rate (hr^{-1}) (see Assumption 4.3.7).

U = Unit conversion factor from hr to s.

The CEDE can be calculated from the airborne radionuclide concentration by [DIRS 160582, NRC 2003, section 4, page 9]:

$$CEDE_i = C_i \times \text{B-Rate} \times T \times U_1 \times DCF_i \times U_2 \qquad \text{(Eq. 4)}$$

where:

$CEDE_I$ = Committed effective dose equivalent of radionuclide *i* (mrem).

B-Rate = Worker breathing rate, 3.33E-4 m^3/s (10 CFR Part 20, Appendix B, Footnote to Table 1).

T = Duration of exposure for routine release in a year (hr) (see Assumption 4.3.5).

DCF_i = Inhalation dose conversion factor for radionuclide *i* (Sv/Bq).

U_1 = Unit conversion factor from s to hr.

U_2 = Unit conversion factor from Sv/Bq to mrem/Ci using $3.7\text{x}10^{+15}$.

4.2.4 DDE and TEDE

DDE is calculated as:

$$DDE_i = [C_i \text{ x } T \text{ x } U_1 \text{ x } ACF_i \text{ x } U_2] + ED_g \qquad \text{(Eq. 5)}$$

DDE_i = Deep dose equivalent of radionuclide *i*.
T = Duration of exposure for routine release in a year (hr) (see Assumption 4.3.5).
ACF_i = Submersion dose conversion factor for radionuclide *i* ($\text{Sv-m}^3\text{/Bq-s}$).
U_1 = Unit conversion factor from s to hr.
U_2 = Unit conversion from $\text{Sv-m}^3\text{/Bq-s}$ to $\text{mrem-m}^3\text{/Ci-s}$ (using definitions Bq=2.7E-11 Ci, and Sv=100remx1E+3mrem/rem= 1E+05mrem) is $3.7\text{x}10^{+15}$.

Individual annual TEDE is calculated as [DIRS 160582, NRC 2003, section 4, page 10]:

$$TEDE_{i,g} = CEDE_i + DDE_i \qquad \text{(Eq. 6)}$$

where:

$TEDE_{i,g}$ = Individual work group member total effective dose equivalent for radionuclide *i* (mrem) (see Assumption 4.3.3).

$CEDE_i$ = Committed effective dose equivalent for radionuclide *i* (mrem).

DDE_i = Deep dose equivalent for radionuclide *i* (mrem).

Collective annual TEDE is calculated as:

$$TEDE_{i,c} = TEDE_{i,g} \text{ x } WG_g \qquad \text{(Eq. 7)}$$

where:

$TEDE_{i,c}$ = Collective total effective dose equivalent for radionuclide *i* (person-mrem).
WG_g = Total number of individual workers per work group *g* (see Assumption 4.3.3).

4.3 ASSUMPTIONS

4.3.1 Dose Rate and the Cask Model

The dose rates in the immediate vicinity of the universal transport cask (Table 2) are used to estimate dose rates received by workers while processing a transportation cask in the TCRRF. It is assumed that the 2 m dose rates of the universal transport cask and the radial dose distance factor computed for the TN-32 cask (BSC 2004 [DIRS 171772], Table I-5) can be used to estimate dose rates received by workers at various distances from the exterior surfaces of a transportation cask. The 2 m dose rates from the radial, top, and bottom surfaces of the universal transport cask are 9.6, 0.1, and 1.3 mrem/hr, respectively (Table 2). These dose rates are scaled up to 10.0, 0.1, and 1.35 mrem/hr so that the 10 mrem/hr at 2 m from the surface represents the bounding case for cask external radiation level limits specified by 10 CFR 71.47.

It is also assumed that the dose rate received by TCRRF workers at 2 m is the weighted average value of the bounding radial, top, and bottom dose rates, or (50%) (10.0) + (25%) (0.1) + (25%) (1.35) = 5.36 mrem/hr (See Table 2). The dose rates for TCRRF workers at 1, 5, 10 and 15m are then estimated using this 2 m dose rate and the radial dose distance factors derived from the TN-32 cask in Table I-5 of BSC 2004 [DIRS 171772].

Rationale: The universal transport cask is designed to meet 10 CFR Part 71 licensing requirements for radioactive material transport packages (NAC International 2002 [DIRS 164612], Section 1.1 and Section 4.4.2. The radial dose distance factor computed for the TN-32 cask (BSC 2004 [DIRS 171772], Table I-5) is representative of rail transportation casks such as the universal transport cask because they have similar exterior dimensions.

Usage: This assumption is summarized in Tables 2 and 3.

4.3.2 Number of Work Shifts in the TCRRF

A minimum of five work shifts is assumed for the TCRRF personnel.

Rationale: This minimum is deemed reasonable for a 24 hour, 7 days a week continuous TCRRF operations.

Usage: This assumption is used in Equation 1 and sections 6.1 and 6.2.1.

4.3.3 Number of Crew Members for the TCRRF

One TCRRF crew is assumed to consist of 1 TP, 3 COs, 1 HP, 1 GO, and 2 SPs.

Rationale: This assumption was based in part on the number of workers and tasks described in the GA-4 Cask Safety Analysis Report for Packaging (General Atomics 1998 [DIRS 103042], Section 7) as well as the anticipated personnel needed to conduct the process step tasks detailed in Table 1.

Usage: This assumption is used in worker dose calculations in Attachment I using Equation 7 and Section 6.2.1.

4.3.4 Approximate Worker Distances from the Transportation Cask

The various worker locations throughout the TCRRF in terms of distances from the transportation cask (Table 1) are estimated from the approximate lengths of the reach tools used as well as the likely worker locations to perform the cask preparation operations in the TCRRF.

Rationale: This assumption reflects the approximate worker locations for the required cask preparation operations in the TCRRF.

Usage: This assumption as shown in Table 1 is used in the worker dose calculations in Attachment I using Equation 1.

4.3.5 Annual Number of Work Hours in the TCRRF

The TCRRF worker is assumed to spend 2000 hrs/yr inside the TCRRF for dose contributions from an airborne source.

Rationale: This value for the airborne source bounds the number of hours a typical worker will spend inside the TCRRF during the year working a regular schedule.

Usage: This assumption is used in worker dose calculations in Attachment I using Equations 4 and 5 and Section 6.2.

4.3.6 Exposure Times in the TCRRF

The times under which the TCRRF workers are exposed to radiation while working in the TCRRF are as shown in Table 1.

Rationale: This assumption is based on the times provided for each task associated with cask operations in the GA-9 cask final design report, and with the extensive experience of General Atomics in actual use of truck casks for shipments of gas-cooled reactor spent fuel and BWR control blades (General Atomics 1993 [DIRS 104776], Table 7.5-3). Time estimates were also based on anticipated times to complete tasks performed by TCRRF personnel.

Usage: This assumption was used in worker dose calculations in Attachment I using Equation 1.

4.3.7 Cask Surface Contamination Resuspension Rate

It is assumed that the resuspension rate from the transportation cask surface contamination is 4×10^{-5} /hr.

Rationale: This resuspension factor is the bounding value recommended for aerodynamic entrainment of powders from unyielding surfaces for indoors and outdoors exposed to ambient conditions following an event (DOE 1994 [DIRS 103756], Section 5, p. 5-7).

Usage: This assumption is used in worker dose calculations in Equation 3 and Section 6.2.

4.3.8 Inhalation of Airborne Radionuclides

It is assumed in the dose calculations that all released or suspended radioactive particles are respirable.

Rationale: This assumption is appropriate because it yields the most conservative dose values.

Usage: This assumption is used in worker dose calculations in Attachment I using Equation 3.

4.3.9 Air Exchange Rate and Composition in the TCRRF

The air change rate in the TCRRF area during normal operations is assumed to be four air changes per hour and ten percent of the air exchange is outside air makeup.

Rationale: The ventilation rate for the TCRRF is based on a minimum of four air changes per hour (BSC 2004 [DIRS 171599], Section 4.8.2.3.5). A minimum of ten percent of the air exchange is outside air makeup (BSC 2004 [DIRS 171599], Section 4.8.2.3.4).

Usage: This assumption is used in worker dose calculations (Attachment I) using Equation 2 and Section 6.2.

4.3.10 Identity of Airborne Radionuclides and the Cask Surface Area Contamination Limits

The most significant radioactive isotope released is assumed to be Cobalt-60 (Co-60), and the surface contamination of the Co-60 on the transportation casks is assumed to be 220 dpm/cm^2.

Rationale: Co-60 is assumed because any contamination on the exterior surface of the transportation cask is likely to come from the radioactive particulates suspended in the spent fuel pool water at the originating nuclear power plant. At the time of loading, most of the particulates in the pool are the long half-life corrosion products from SNF surfaces that might dislodge during SNF movement. The most prominent particulates are Co-60, Co-58, Iron-55, Iron-59, Manganese-54, Chromium-51, and Zinc-65 (NRC 2001 [DIRS 157761], Section 4.7.2.3, p. 4-51). Of these products, Co-60 has the lowest derived air concentration of 1.0E-8 Ci/m^3 for class Y radioactive material (10 CFR Part 20, Column 3 of Table 1 of Appendix B) and the longest half-life of 5.27 years (Kocher 1981 [DIRS 105622], p. 78). Also, all other particulate sources including fission products (e.g., Sr-90 and Cs-137) and actinides (alpha emitters) are at a minimum or insignificant, relative to Co-60 in terms of potential contamination levels.

The contamination limits for exclusive-use shipments by rail or highway (i.e., vehicles dedicated solely to the transport of radioactive packages and are appropriately marked on the exterior "For Radioactive Materials Use Only"), may not exceed 10 times the limits for non-exclusive use shipments contained in Table 11, of 49 CFR 173.443 (Section 4.4.3), Contamination Control. The use of the maximum allowable removable surface contamination value during exclusive-use transport is appropriate because it is a bounding condition and will yield conservative dose values.

Usage: These assumptions are used in worker dose calculation in Equation 3 and Section 6.2.

4.3.11 Extent and Mobility of the Cask Surface Contamination

Surface contamination is assumed to cover the entire external surface of the transportation cask, and all of the contamination is assumed to be removable and releasable to the atmosphere.

Rationale: The amount of surface contamination assumed to be available for release to the atmosphere using the resuspension rate discussed in Assumption 4.3.7 is significantly higher than is anticipated for transportation casks to be handled at the TCRRF. This is because only a small portion, if any, of the cask's exterior would have any removable contamination due to the preventive measures used during underwater loading at the originating nuclear power plant. The originating nuclear power plant would decontaminate the exterior of the cask to the acceptable level prior to shipment. Surveying of the cask's exterior for contamination will also be performed upon the receipt of the cask at the TCRRF. Therefore, the amount of removable contamination available hypothetically to become airborne under normal conditions in the TCRRF would be significantly less than the amount assumed.

Usage: This assumption is used in worker dose calculations using Equation 3 and in section 6.2.

4.3.12 Maximum Airborne Radioactivity in TCRRF

Airborne radioactivity dose calculation is based on contamination on all six casks inside TCRRF. It assumed that all casks have surface contamination to the maximum allowable limit. The surface area of the cask is estimated to be 289 m^2 (see Attachment I), which is representative of a universal multipurpose canister system cask of length 5.3 m and radius 1.18 m (NAC International 2002, Table 1.2-1).

Rationale: This assumption is consistent with the design capacity of the TCRRF and incorporates conservatism to doses from the airborne source.

Usage: This assumption is used in worker dose calculations using Equation 3.

4.3.13 Affected Volume of the TCRRF

A height of 20 ft (6.096 m), truncated from 43 ft, 9 in., length of 225 ft (68.580 m) (BSC 2004 [172144]) and width of 131 ft (39.929 m) (BSC 2004 [168452]) are used in the calculation of the affected volume (m^3) of the TCRRF.

Rationale: This height reduction increases the Co-60 airborne concentration in the worker area; hence, yielding conservative doses from airborne radioactivity.

Usage: This assumption is used in worker dose calculation in Equation 2.

4.3.14 Annual Number of Casks Handled in the TCRRF

The total number of transportation casks that will be shipped to the repository annually is assumed to be 507 (BSC 2003 [DIRS 165990], Table 16).

Rationale: This annual cask arrival represents a realistic and reasonable number of commercial transportation casks that the TCRRF will have to process.

Usage: This assumption is used in Section 6 and Attachment I.

4.3.15 Average Dose Rate Reduction Factor

The average external dose rate from SNF cask received is one-fifth of the design-basis dose.

Rationale: All transportation casks are required to meet the external radiation level limits specified by 10 CFR 71.47 (Section 4.4.2). The design basis PWR SNF characteristics at the repository are 4 percent initial enrichment, 60 GWd/MTU burnup and 10 year cooling, (BSC 2002 [161120], section 5.5.2) the average SNF characteristics are 4 percent enrichment, 48 GWd/MTHM burnup, and cooled for 25 years (BSC 2004 [169061], Attachment IX). Dose rates based on the average SNF at the repository are more representative and appropriate for worker dose assessment. Based on dose ratios derived in *Dry Transfer Facility Worker Dose Assessment* (BSC 2004 [171772], Table I-5), the dose rate reduction factor from design-basis SNF to the average SNF received at the repository is about 5.

Usage: This assumption is used in Attachment I for dose calculations.

4.4 REGULATIONS

4.4.1 10 CFR 20.1201

The regulation applicable to worker doses is contained in 10 CFR 20.1201, *Occupational Dose Limits for Adults*:

(a) The licensee shall control the occupational dose to individual adults to the an annual limit of the TEDE being equal to 5 rems.

4.4.2 10 CFR Part 71.47

0.1 mSv/h (10 mrem/h) at any point 2 meters (80 in.) from the outer lateral surfaces of the vehicle (excluding the top and underside of the vehicle); or in the case of a flat-bed style vehicle, at any point 2 m (6.6 feet) from the vertical planes projected by the outer edges of the vehicle (excluding the top and underside of the vehicle);

4.4.3 49 CFR 173.443

Non-fixed (removable) contamination limits:

a) Less than or equal to 220 dpm/ cm^2 averaged over 300 cm^2 $\beta-\gamma$
b) Less than or equal to 22 dpm/ cm^2 averaged over 300 cm^2 α

4.5 CRITERIA

ALARA design goals (BSC 2004 [DIRS 171599], Section 4.9.3.3) for occupational workers ensure that both individual and collective annual doses are maintained at ALARA levels during normal operations and as a result of Category 1 event sequences. The following ALARA design goals are established for the design process.

> "The ALARA design goal for individual radiation worker doses is to minimize the number of individuals that have the potential of receiving more than 500 mrem/yr total effective dose equivalent (TEDE). That goal is 10% of the annual TEDE limit in 10 CFR 20.1201, and includes both internal and external exposures."

5. USE OF SOFTWARE

Microsoft Excel 97 (spreadsheet program) is used to perform simple calculations. User-defined formulas, input, and results are documented in sufficient detail in Section 6 and Attachment I to allow for independent duplication of the various computations without recourse to the originator. This software is exempt from the requirements of LP-SI.11Q-BSC, *Software Management*.

6. CALCULATIONS

6.1 WORKER DOSE FROM CONTAINED SOURCE

Using the equations and assumptions of Section 4, external dose is calculated by worker group in Attachment I. The five worker groups (TP, CO, HP, GO, and SP) in the TCRRF perform job functions requiring different time intervals and distances from the shipping casks. Table 4 summarizes external dose per cask processed and annual dose for each member of a worker group. Total expected time duration per cask for the governing process step is the summation of its subprocess step times (Table 1). Total dose per cask are based on distance for each subprocess step (Table 1) and are read from Table 3 then summed together for each governing process step. Equation 1 is used to determine the annual dose from the contained source.

Table 4. Summary of TCRRF Worker Dose Due To Direct Exposure by Group

Worker Group (1)	Bounding External Dose per Cask (mrem/cask) (2)	Annual Average External Individual Dose (mrem/yr) (3)
Transportation Personnel (TP)	2.6	260
Cask Operator (CO)	6.1	620
Health Physicist Technician (HP)	1.1	110
Gantry Operator (GO)	1.3	130
Security personnel (SP)	0.3	30

NOTES: (1) TCRRF Worker Group from section 3.
(2): Calculated in Attachment I using Excel spread sheet program based on 10 mrem/hr dose rate limit at 2 m radial distance (Table 2)
(3) = (2) × 507 (Assumption 4.3.14) / 5 (Assumption 4.3.2)

6.2 WORKER DOSE FROM AIRBORNE SOURCE

Table 5 is a listing of numerical values and their sources calculated or used in Attachment I using the equations of Sections 4.2.3 and 4.2.4 to calculate CEDE and airborne source contribution to the DDE.

Table 5. Numerical Values used for Airborne CEDE and DDE Calculation

Parameter	Value	Final Units	Source
Airborne concentration of Co-60	5.95E-13	Ci/m^3	Calculated with Eq. 3
Inhalation Co-60 dose conversion factor	1.10E+08	mrem/Ci	ICRP 1995 [DIRS 172721],Tables B.1,C.1.
Air immersion Co-60 dose conversion factor	5.37E+02	$mrem-m^3/Ci-s$	Eckerman 1993 [DIRS 107684], Table III-1
Maximum allowable Co-60 surface contamination	9.91E-07	Ci/m^2	Assumption 4.3.10
Surface area of 6 casks	289	m^2	Attachment I
Resusupension rate	4.00E-05	hr-1	Assumption 4.3.7
Volume of TCRRF	16693	m^3	Assumption 4.3.13
Fraction of outside air makeup	0.1	N/A	Assumption 4.3.9
Air exchange rate	4	hr-1	Assumption 4.3.9
Volumetric flow rate	1.85	m^3/s	Calculated with Eq. 2
Worker breathing rate	3.33E-04	m^3/s	(20,000 ml/min): 10 CFR Part 20. Appendix B
Duration of exposure (hrs)	2000	hrs	Assumption 4.3.5

6.2.1 Worker TEDE

Annual TEDE per individual worker determined from Equation 6 is 260, 620, 110, 130, and 30 mrem for TP, CO, HP, GO, and SP, respectively. TEDE from airborne source is insignificant when compared to dose received from direct exposure from contained sources and therefore is deemed negligible. All calculations of external dose, CEDE, and DDE using the equations of Section 4 are detailed in Attachment I.

Collective annual TEDE from Equation 7 is 1.3, 9.2, 0.55, 0.66, and 0.3 person-rem for TP, CO, HP, GO, and SP, respectively. The sum of these collective annual TEDEs is 12 person-rem. Table 6 summarizes the above dose calculations.

Table 6. Average Dose for the TCRRF Workers

Worker (1)	Cask External TEDE (mrem/yr) (2)[a]	Airborne Exposure TEDE (mrem/yr) (3)[a]	Total TEDE (mrem/yr) (4)	Number of Workers per Shift (5)	Number of Crews (6)	Collective TEDE (person-rem)/yr (7)
TP	2.6E+02	4.6E-01	2.7E+02	1	5	1.3E+00
CO	6.2E+02	4.6E-01	6.2E+02	3	5	9.2E+00
HP	1.1E+02	4.6E-01	1.1E+02	1	5	5.5E-01
GO	1.3E+02	4.6E-01	1.3E+02	1	5	6.6E-01
SP	3.0E+01	--	3.0E+01	2	5	3.0E-01
Total	--	--	--	--	-	1.2E+01

NOTES: [a]Calculated in Attachment I.

(4) = (2) + (3)

(5): Assumption 4.3.3

(6): Assumption 4.3.2

(7): (4) × (5) × (6) / 1000 (rem/mrem).

7. RESULTS

Individual and collective doses to the TCRRF worker are estimated using the methodology described in Section 3, process steps listed in Section 4.1, equations described in Section 4.2, assumptions defined in Section 4.3, the software described in Section 5, and the calculations performed in Section 6 and Attachment I. Appropriate and conservative input data and assumptions support the parameters used in the dose calculations. The outputs are reasonable compared to the inputs and the results are suitable for the intended use

Annual average TEDE per individual worker is 270, 620, 110, 130, and 30 mrem for TP, CO, HP, GO, and SP respectively (Table 6, Column 4). Higher CO doses for process in TCRRF are attributed to their process steps, which have the closest distance proximity to the transportation cask when compared to the other worker groups (Table 1). An ALARA design and operations review would recommend ways to reduce the dose to all worker types. Certain other activities at the facility, such as returning the empty transporter to parking areas will expose TP to low levels of radiation in the area. These doses, however, would be small compared to the direct exposure from handling loaded casks due to the fact that shipping casks do not contain radioactive components and no maintenance is anticipated. TCRRF worker dose assessed in this report is conservative since it based on rail shipment that results in higher doses compared to that based on truck shipment. The maximum overall shipment of 507 used in this calculation includes about 1/3 truck shipment, and no credit is taken to the reduced dose rate corresponding to truck casks. Annual TEDE (0.91 mrem) from exposure to airborne source is insignificant when compared to doses received from direct exposure to contained sources and therefore is deemed negligible.

7.1 COMPARISON WITH REGULATORY LIMITS

All annual individual doses, predominantly due to direct exposure, calculated in Section 6 are a factor of 8 or more times lower than NRC regulatory limit of 5 rem/yr TEDE (Section 4.4.1).

7.2 COMPARISON WITH ALARA GOAL

All annual individual doses calculated in Section 6 are lower for all the work groups except that it is slightly higher for COs than ALARA design goal of 500 mrem/yr TEDE (Section 4.5).

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8.2 CODES, STANDARDS, REGULATIONS AND PROCEDURES

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ATTACHMENT I
LISTING OF ELECTRONIC FILE IN CD CONTAINING WORKER DOSE CALCULATIONS

The electronic file (Microsoft Excel workbook) of TCRRF worker dose calculations is provided on a compact disk as Attachment I. The worksheet file name and properties on the compact disk are listed in Table I-1.

Table I-1. Worksheet Name and Properties in the Attachment I Compact Disk

Worksheet Name	Description	File Size (Bytes)	Date	Time
TCRRF ATT_Rev-B 2-15-05.xls	TCRRF Worker Dose Assessment	79872	February 15, 2005	8:11 AM

The above listed file has been saved on a CD-ROM disk that is included as an attachment to this document.